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Measurement of motor vehicle speed as an input parameter in models for predicting noise levels

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ABSTRACT

Motor vehicle speed is one of the inputs used to develop models for predicting road traffic noise levels. In existing models, the vehicle speed used as input to estimate the noise level is not the current (measured) speed, but the vehicle speed determined based on the speed limit by road type or vehicle type. Therefore, the development of a device for measuring vehicle speed using radar that works on the principle of Doppler effect, which is presented in the paper. The advantage of this measuring device is the low price compared to similar devices, easy use and the possibility of easy processing of data obtained by measurement. The device allows measuring speed in all weather conditions in terms of temperature, precipitation and time of day. Then, in real time, it displays the speed and direction of movement of the vehicle on the screen of the mobile phone, and in the stationary laboratory, remote control, adjustment and adjustment of the software for measuring speed is enabled.

KEYWORDS

Noise level, Road traffic, Vehicle speed, Noise level predicting model

1. INTRODUCTION

Different models for predicting noise levels use speed to predict noise levels in different ways, so some of them are presented. Of course, it should be noted that in addition to these, there are other models that do not use the speed of the vehicle to predict noise levels.

1.1. CoRTN model

CoRTN model [1] [2] (Calculation of Road Traffic Noise) was developed in cooperation between TRRL (Transport and Road Research Laboratory) and the Ministry of Transport of the United Kingdom in 1975, and was modified in 1988. According to this model, the value of noise level generated by road traffic at a distance of 10 m from the closer edge of the road, which is exceeded during 10% (observed) of one-hour time interval can be estimated using the following equation (1):

$$L_{10}(1h) = 42{,}2 + 10\,logQ + \Delta L_V + \Delta L_S + \Delta L_P + \Delta L_\alpha\ [dBA] \tag{1}$$

where:

Q – flow of motor vehicles (vehicles / hour),

ΔL_V – correction of noise levels for the impact of vehicle speed and the percentage of heavy vehicles,

ΔL_S – correction of noise levels to influence the slope of the road,

ΔL_P – correction of noise levels for the impact of the road curtain,

ΔL_α – correction of noise levels in the case of a line source of limited length.

An average speed of 75 km/h or a speed corresponding to the type of road is used to calculate the noise level.

1.2. RLS-90 model

RLS-90 model [1] [3] was developed by the Ministry of Transport (Road Construction Department) of the Federal Republic of Germany in 1990 to predict road traffic noise. This model establishes a connection between the parameters of traffic flow (vehicle flow, percentage of heavy vehicles, speed limit) and the average noise level at a distance of 25 m from the road axis. According to the RLS-90 model, the value of noise levels in the open space without vertical obstacles can be estimated as follows (2):

$$L_0 = 37,3 + 10 \log (Q (1 + 0,082p)) + \Delta L_V + \Delta L_S + \Delta L_P \ [dBA] \quad (2)$$

Wherein:

Q – flow of motor vehicles (vehicles / time),

p – share of heavy vehicles in traffic flow (%),

ΔL_V – correction of noise levels for the impact of vehicle speed,

ΔL_S – correction of noise levels for the influence of road slope,

ΔL_P – correction of noise levels for the impact of the road curtain,

In this model, the speeds of passenger vehicles from 30 km/h to 130 km/h and the speeds of trucks from 30 km/h to 80 km/h are used to predict the noise of road vehicles.

1.3. Burgess model

This model [4] was developed at the National Physics Laboratory in Sydney. During the measurement, the traffic was free, on a flat road, without traffic signals. The analysis developed the equation for the equivalent noise level of road traffic and is presented as follows (3):

$$L_{eq} = 55 + 10.2 \log Q + 0.3p - 19.3 \log d \quad (3)$$

Wherein:

Q – total number of vehicles,

p – share of heavy vehicles in traffic flow (%),

d – distance.

This model gives a satisfactory correlation value of 0.95 with a standard error of 1.5 dB compared to the measured Leq, noting that heavy vehicles greatly affect the noise level and that not taking into account the speed of the vehicle simplifies the model applies in uninterrupted traffic conditions in Australia.

1.4. ASJ RTN - model 2018

The model [4] [5] for predicting noise levels began to develop in the 1970s in Japan.

The model is based on certain conditions such as road type (pavement, road dimensions, signalized / non-signalized road sections), traffic volume, vehicle speed (interrupted / uninterrupted traffic flows), road length and meteorological conditions.

ASJ RTN-Model 2018 calculates noise levels of different vehicles depending on vehicle speed, engine speed and engine load, and the model is expressed as a function of vehicle speed, although the change in noise levels is due to the type of road and road slope and type and type vehicles. The noise level of road vehicles is calculated as follows (4):

$$L_{wA} = a + b \log V + C \quad (4)$$

Wherein:

a, b – regression coefficient,

V – vehicle speed (km / h),

C – benchmark correction factor.

$C = \Delta L_{grad} + \Delta L_{dir} + \Delta Letc$

ΔL_{grad} is the correction for road gradient [dB],

ΔL_{dir} is the correction for sound radiation directivity [dB], and

ΔL_{etc} is the correction for other factors [dB]

provided that the model is especially used for sections with uninterrupted traffic flows (highways, motorways) with vehicle speeds of 40 to 140 km / h and for sections with interrupted traffic flows (intersections) with vehicle speeds of 10 to 60 km / h .

1.5. CNOSSOS model

In order to achieve a joint program to address environmental noise, the Council of Ministers of the European Union approved in 2002 Directive 2002/49 / EC on the assessment and management of environmental noise, which provides for a number of activities to implement measures that would contribute to avoiding, preventing or reducing the harmful effects of noise in the environment.

In accordance with Article 6.2 of Directive 2002/49 / EC, in 2012 the European Commission developed Common Noise Assessment Methods (CNOSSOS-EU) for road, rail and air transport, as well as industrial noise, which is applied in for the purpose of strategic noise mapping in accordance with Article 7 of the Directive, binding from 2019 in all EU countries.

CNOSSOS EU [6] aims to improve the reliability, consistency, and comparability of noise assessment results in EU Member States based on data from successive noise mapping cycles.

The source of road traffic noise is determined by combining the noise emissions of all individual vehicles that form the traffic flow. These vehicles are divided into five separate groups based on noise emission characteristics (1: light motor vehicles, 2: medium motor vehicles, 3: heavy motor vehicles, 4: two-wheeled motor vehicles and 5: open vehicle category

Each road vehicle emission model is represented by a set of mathematical equations that represent two main noise sources:

1. rolling noise, caused by the interaction of tires and road and
2. vehicle propulsion system noise (engine, exhaust system).

Rolling noise is defined by the equation (5):

$$L_{WR,i,m} = A_{R,i,m} + B_{R,i,m} log(\frac{v_m}{v_{ref}}) + \Delta L_{WR,i,m} \tag{5}$$

Vehicle propulsion system noise is defined by the equation (6):

$$L_{WP,i,m} = A_{P,i,m} + B_{P,i,m} \left(\frac{v_m - v_{ref}}{v_{ref}} \right) + \Delta L_{WR,i,m} \tag{6}$$

Wherein:

$A_{P,i,m}$ and $B_{P,i,m}$ – octave band coefficients for each vehicle category,

v_{ref} - reference speed 70 km / h,

v_m - speed according to the type of vehicle (km/h),

$\Delta L_{WP,i,m}$ – speed according to vehicle type (km / h).

The coefficients $A_{P,\,i,\,m}$ and $B_{P,\,i,\,m}$ are given by octave bands for each vehicle category and for the reference speed v_{ref} = 70 km/h. ΔLWP, i, m is equal to the sum of the correction factors to be applied to the drive noise emission for special driving conditions or conditions other than the reference conditions.

vm represents speed according to the type of vehicle, with the definition that in most cases it is less than the speed limit according to the type of road and the highest speed according to the type of vehicle, assuming that all vehicles by category move at the same speed.

Based on the previously presented models for predicting road traffic noise, it can be seen that some models neglect vehicle speed due to model simplicity (Burgess model), some models such as CoRTN model and RLS-90 model use speed to correct noise levels, and ASJ RTN - the 2018 model and the CNOSSOS model use vehicle speed as one of the main factors for calculating noise levels.

2. CHARACTERISTICS OF SPEED MEASURING DEVICES

Some of the models that predict the noise level use the speed of the vehicle as one of the parameters. The speed used is usually not the current speed of the vehicle, but the speed that is defined on the basis of the speed limit for a certain type of road or for a certain type of vehicle on certain roads. An analysis of existing speed measurement systems has shown that their price is relatively high, that some are very difficult to use (eg speed radars used by the police), and that some of them cannot fully meet the required measurement requirements. speed.

In order to overcome the above problems, a speed measuring device was made. The speedometer consists of a radar, a camera, a mini PC housed in a housing, a power battery and a mobile phone. In the following text, the characteristics of individual elements of the speed measuring device will be presented.

2.1. Radar

The radar used in the speedometer is made by OmniPreSense model OPS243. The OmniPreSense OPS243 is a short-range radar that detects movement, measures speed and direction. The OPS243 block diagram of the radar is given in Figure 1.

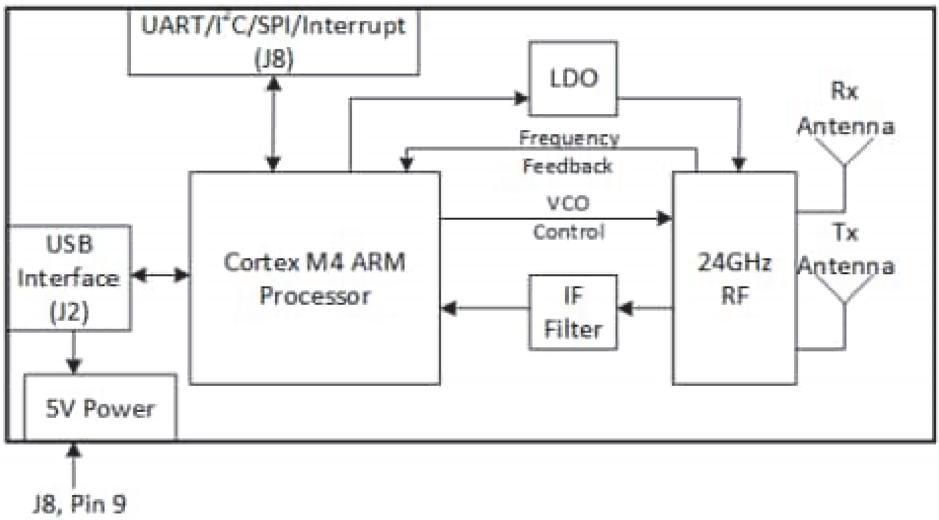


Figure 1: OPS243 radar block diagram

Radar signals are processed by an on-board processor which communicates via the API. The OPS243 communicates with the Raspberry Pi mini via a mini USB port. This radar detects (Figure 2) pedestrian-like objects at a distance of 25 m, large metal-like objects at a distance of up to 100 m, with a maximum speed of up to 222 km / h. The radar beam of measurement is 20o wide, consumption 1.7 W, in hibernation up to 0.2W and operating temperature from -40oC to +85oC.

Radar (Figure 3) works on the principle of Doppler effect, continuously sends fixed frequency radio waves that strike an object (vehicle) moving towards or from the radar. The frequency of the reflected radio wave is changed, and the speed of the moving object is obtained from the difference in frequency between the emitted and reflected radio waves.

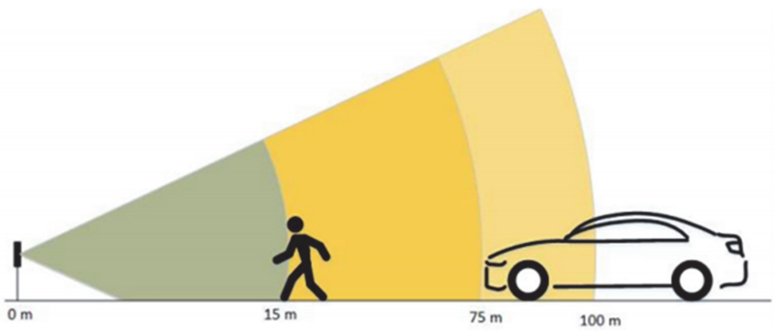


Figure 2: The distance at which moving objects are detected

If a radio wave is transmitted to a moving object moving away from the radar, each subsequent wave travels a greater distance to the object before it is reflected to the radar. Each subsequent wave travels longer, so the wavelength increases, while the frequency decreases. In case the radio wave is transmitted towards an object approaching the radar, each subsequent wave travels a smaller distance, so the wavelength decreases and the frequency increases.

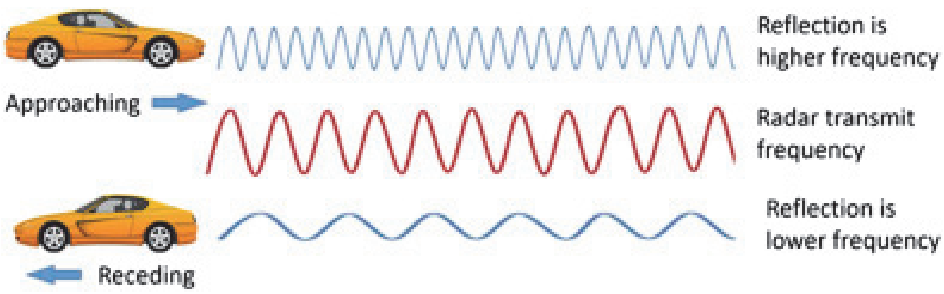


Figure 3: Principle of Doppler effect

2.2. Camera

Raspberry Pi V2 camera, uses Sony IMX219 8 mega pixel sensor. The camera is used to record videos and photos. It supports 1080p30, 720p60 and VGA90 video mode, connects via a 15 cm cable to the CSI port on a Raspberry Pi mini computer.

2.3. Mini PC

The Raspberry Pi 3 mini PC uses the Linux debian operating system. The Raspberry Pi 3 mini PC features a 64-bit quad-core 1.4GHz processor, 2.4GHz dual-band and 5GHz wireless LAN, Bluetooth 4.2 / BLE, faster Ethernet and PoE (Power over Ethernet). The mini PC is used in the unit for measuring speed due to its simple programmability.

Dedicated mini PC software downloads data from the radar API, collects photos taken with the camera and records the speed at the time of shooting. The device records the measured speed, at a certain magnitude of the reference signal, and the frequency of recording speed can be changed and adjusted via the API. Recorded data is stored on a micro SD card. All measurements are monitored over the network, and the mini PC is accessed from a web browser.

On the screen of the mobile phone, real-time video from the camera as well as the speed and direction of movement of the vehicle can be viewed via a web browser (it is not necessary to install any additional monitoring application on the phone). The mini PC computer accesses the hotspot via Wi-Fi (the hotspot function allows the Internet to be shared with other devices via mobile phones) activated on the mobile phone, thus enabling the mini PC to have internet access.

Since the Raspberry Pi 3 mini PC does not have a real-time clock on it, the correct time is set via the Internet. The mini computer makes a VPN connection to the stationary laboratory where the central computer is located, which enables the Raspberry Pi 3 computer to be accessed from the stationary laboratory in the field where the measurements are performed. In this way, remote control, adjustment and adjustment of speed measurement software is enabled. When measuring speed, the device can be set not to record a speed measured below a certain speed or only to record a speed measured above a certain speed.

3. RESULTS AND DISCUSSION

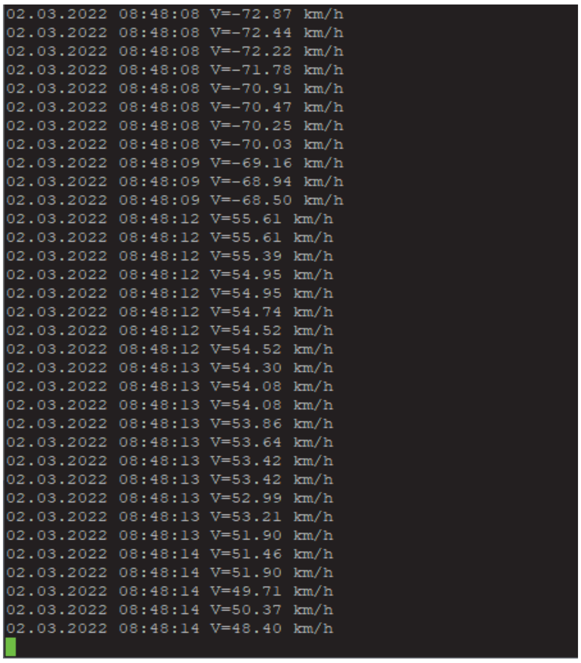
Figures 4, 5 and 6 give some of the possible views recorded by the speed measuring device. Figure 4 shows the measured speed (positive value) of the vehicle on arrival with the date (day.month.year) and time (hour: minute: second) when the speed measurement was performed, while Figure 5 shows the measured speed negative value) of the outgoing vehicle with the display of the date and time when the speed measurement was performed.

Figure 4. Recording the speed of movement vehicles; vehicle on arrival

Figure 6 shows all measured speeds by radar, ie more measured speeds per second, but the device is set to record one measured speed per second and this speed is shown in the image. This setting may be different, ie the device can record the speed several times per second, but for the type of measurements required, this is a satisfactory frequency of recording the measured speed.

Figure 5. Recording the speed of movement vehicles; outgoing vehicle

In order for the speed measuring device to have a practical application, it was calibrated with a laser radar TLaser III type B-1-32, serial number 110135 used by the Ministry of Interior of the Republic of Serbia, Traffic Police Administration and has a Certificate of verification valid until 30 June 2022. During the control measurement to check the correctness of the measurement, the speed measuring device showed identical results as the laser radar TLaser III, so it can be used during any speed measurement.



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02.03.2022 08:48:08 V=-72.87 km/h
02.03.2022 08:48:08 V=-72.44 km/h
02.03.2022 08:48:08 V=-72.22 km/h
02.03.2022 08:48:08 V=-71.78 km/h
02.03.2022 08:48:08 V=-70.91 km/h
02.03.2022 08:48:08 V=-70.47 km/h
02.03.2022 08:48:08 V=-70.25 km/h
02.03.2022 08:48:08 V=-70.03 km/h
02.03.2022 08:48:09 V=-69.16 km/h
02.03.2022 08:48:09 V=-68.94 km/h
02.03.2022 08:48:09 V=-68.50 km/h
02.03.2022 08:48:12 V=55.61 km/h
02.03.2022 08:48:12 V=55.61 km/h
02.03.2022 08:48:12 V=55.39 km/h
02.03.2022 08:48:12 V=54.95 km/h
02.03.2022 08:48:12 V=54.95 km/h
02.03.2022 08:48:12 V=54.74 km/h
02.03.2022 08:48:12 V=54.52 km/h
02.03.2022 08:48:12 V=54.52 km/h
02.03.2022 08:48:13 V=54.30 km/h
02.03.2022 08:48:13 V=54.08 km/h
02.03.2022 08:48:13 V=54.08 km/h
02.03.2022 08:48:13 V=53.86 km/h
02.03.2022 08:48:13 V=53.64 km/h
02.03.2022 08:48:13 V=53.42 km/h
02.03.2022 08:48:13 V=53.42 km/h
02.03.2022 08:48:13 V=52.99 km/h
02.03.2022 08:48:13 V=53.21 km/h
02.03.2022 08:48:13 V=51.90 km/h
02.03.2022 08:48:14 V=51.46 km/h
02.03.2022 08:48:14 V=51.90 km/h
02.03.2022 08:48:14 V=49.71 km/h
02.03.2022 08:48:14 V=50.37 km/h
02.03.2022 08:48:14 V=48.40 km/h
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Figure 6. Recording of all speeds from the radar

4. CONCLUSION

The measuring device performs stationary measurement and was primarily developed for measuring vehicle speed as one of the input parameters in the noise prediction model. In addition to this purpose, the measuring device can also be used for other vehicle speed measurements in order to record the vehicle speed on certain sections of the road. Further development of the measuring device aims at the device, in addition to measuring speed, also counting vehicles and recognizing the type of vehicle (motorcycles, passenger, cargo, etc.) in order to obtain the most accurate input data for predicting noise levels of road traffic. In addition to this, based on the measured values of speeds, it will be possible to form a model for planning road traffic noise for different values of vehicle speed, e.g. in the settlement, outside the settlement, motorway and highway.

5. LITERATURE

[1] J. Tomić, “Application of soft computing techniques for predicting road traffic noise levels”, PhD Thesis, University of Belgrade (Serbia), (2017)

[2] Department of Transport Welsh office, “Calculation of road traffic noise”, London, (England), (1988)

[3] Der Bundesminister für Verkehr, “Richtlinien für den Lärmschutz an Straßen RLS-90”, (1990)

[4] F. Ibili, E. K. Adanu, C. A. Adams, S. A. Andam-Akorful, S S. Turay and S. A. Ajayi, “Traffic noise models and noise guidelines: A review”, Noise & Vibration Worldwide 2021, Vol. 53 (1-2), pp. 65–79, https://doi.org/10.1177/09574565211052693, (2022)

[5] S. Sakamoto, “Road traffic noise prediction model ASJ RTN-Model 2018”, Acoust. Sci. & Tech., Vol. 41, (3), pp. 529-589, https://doi.org/10.1250/ast.41.529, (2020)

[6] S.Kephalopoulos, M. Paviotti, F. Anfosso-Lédée, “Common Noise Assessment Methods in Europe (CNOSSOS-EU)”, (2012)